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Contents

	Page
Hygroscopic Equilibrium of Sunflowerseed, Flaxseed, and Soybeans—*R. K. Larmour, H. R. Sallans, and B. M. Craig* - -	1
Respiration of Whole and Dehulled Sunflowerseed and of Flaxseed—*R. K. Larmour, H. R. Sallans, and B. M. Craig* - -	9
Oil Seeds in Western Canadian Grain Screenings—*J. A. Anderson, W. O. S. Meredith, W. J. Eva, and A. C. Heise* - -	19

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VOL. 22, SEC. F. JANUARY, 1944 NUMBER 1

HYGROSCOPIC EQUILIBRIUM OF SUNFLOWERSEED, FLAXSEED, AND SOYBEANS[1]

BY R. K. LARMOUR[2], H. R. SALLANS[3], AND B. M. CRAIG[4]

Abstract

Equilibrium moisture values for relative humidities of from 31 to 93% were obtained for sunflowerseed, flaxseed, and soybeans. The hygroscopicity of whole sunflowerseed per se is practically the same as that of flaxseed, that of dehulled sunflowerseed is somewhat lower. Soybeans show a hygroscopicity curve quite different from that of flax and sunflowerseed. The differences in these curves are not explainable by either the oil or the ash contents of the seeds.

In studying the respiration rates of seeds, especially at higher moistures, it is necessary to humidify the incoming air to the extent that the grain will not change materially in moisture content during the aspiration. To accomplish this the relative humidities (which will be referred to as *R. H.*) with which the grains are at equilibrium must be known. A very satisfactory and simple method for providing an atmosphere of definite *R. H.* is to pass air at a suitable rate through a continuously saturated solution of certain salts.

A wide range of *R.H.* can be obtained from various pure salts, and salt mixtures, if their solutions are kept saturated and the temperature is maintained within fairly definite limits. This method has several advantages over the use of sulphuric acid solutions, provided one need not insist on an exact prescribed *R.H.* Some of these advantages are:

(*a*) there can be no change in the vapour pressure of the solutions as a result of absorption or loss of vapour from the air, and therefore a much smaller volume of the solution is needed,

(*b*) the solutions may be used indefinitely as long as an excess of the salt is present,

(*c*) they are non-corrosive, and therefore much easier to handle.

In view of these considerations it was decided to ascertain the equilibrium moistures of various oil-seeds, which were to be studied in respect to storage and respiration, at a number of moisture levels. As the moisture levels at

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which the respiration determinations were to be done could be selected from a fairly wide range, the use of saturated salt solutions was indicated as the best method to obtain various *R.H.*'s.

Methods and Materials

A guide to the selection of suitable humidities was available in the work of Coleman and Fellows (1) who reported the equilibrium moistures of various grains at *R.H.*'s ranging from 15 to 100%. From the data of Spencer (3), as reported in the International Critical Tables, salts whose saturated solutions gave *R.H.*'s ranging from about 30 to 93% were selected. The salts used in this study and the *R.H.*'s at 25° C. are listed in Table I.

TABLE I

RELATIVE HUMIDITIES OF SATURATED SOLUTIONS OF VARIOUS SALTS AND SALT MIXTURES AT 25° C.

Salts	Relative humidity at 25° C., %
$CaCl_2 . 6H_2O$	31
K_2CO_3	43
$Ca(NO_3)_2 . 2H_2O$	51
NH_4NO_3	62
$NH_4Cl + KNO_3$ (Mutually saturated)	71.2
$(NH_4)_2SO_4$	81.1
$NH_4H_2PO_4$	93

A comparison of saturated salt solutions and sulphuric acid solutions at one *R.H.* value was made as a check on the method proposed for this study. Four grains, namely, wheat, flaxseed, soybeans, and sunflowerseed, were used in this test. The series was divided and one set of samples was placed over saturated ammonium nitrate solution, and the other over 38.03% sulphuric acid (by weight). Both these solutions should maintain a *R.H.* of 62%.

The data obtained in this study are given in Table II. They show that there is no significant difference attributable to the two methods of control of the *R.H.*

TABLE II

COMPARISON OF EQUILIBRIUM MOISTURES ATTAINED OVER SATURATED AMMONIUM NITRATE SOLUTION AND 38.03% SULPHURIC ACID. *R.H.* = 62%

Grain	Equilibrium moisture contents*, %	
	Over saturated NH_4NO_3	Over 38.03% H_2SO_4
Wheat	13.71	13.72
Soybeans	10.09	10.21
Flaxseed	8.69	8.69
Sunflower (whole seed)	9.25	9.28

* "*Moisture content*" *refers to moisture in material per se.*

The grains used in this study were: Kobott soybeans, obtained from the Central Experimental Farm, Ottawa; Mennonite sunflowerseed obtained from the Dominion Forage Crops Laboratory, Saskatoon; and Bison flaxseed from the Field Husbandry Department of the University of Saskatchewan. All samples were of seed grade and were grown in 1941. As all three grains had been stored in sacks since harvest, their moisture contents were somewhat lower than normal, as can be seen from Fig. 1.

Duplicate samples of 15 to 30 gm. each were placed in copper-wire baskets which were stored in 3-litre containers immersed to the neck in a water-bath kept at 25° C. $\pm$ 0.1°. The saturated salt solutions, together with an excess of the solid salt, were placed in the jar and the baskets were supported above the solutions by wire gauze mats. The baskets were weighed at intervals by removing them and weighing them rapidly on a magnetically damped balance. Weighings were continued until there was no further increase in weight after three successive periods.

Initial moisture of the grains was determined by vacuum oven drying. Final moistures of the samples kept over high humidity had to be done by the two-stage method in which the moist sample was exposed to air in the room first, and then this air-dried sample was ground and finally dried in the vacuum oven. The intermediate moistures, between the beginning and end of the experiment, were calculated from the initial moistures and the periodic weight increase. This procedure is subject to an error that varies with the humidity of the atmosphere to which the grain is exposed. At low humidities the grain never gets very moist and there is very little respiration of the seeds, while at the higher humidities, the grain rises rapidly in moisture content to the point where respiration goes on at an appreciable rate. In these samples there is a steady small loss of dry matter which makes the calculated moistures a trifle low. This error is not, however, great enough to affect the conclusions seriously.

A more serious criticism of this method is that some seeds at the higher *R.H.*'s rapidly get so moist that moulds begin to grow vigorously. The high metabolic rate of these moulds causes an appreciable loss of dry matter and the calculated moisture values are worthless. It is possible that this difficulty might be overcome by changing the method from a static one to a forced draught procedure in which air of proper humidity is drawn continuously through the grain thereby hastening the attainment of equilibrium.

Discussion of Results

The moisture changes in sunflowerseed, flaxseed, and soybeans during the course of the experiment are shown graphically in Fig. 1. It is to be noted that sunflowerseed and flaxseed attained almost equilibrium moisture within three days at all *R.H.*'s except the highest, 93%. Soybeans, on the other hand, even at *R.H.* of 62% showed a slower rate of absorption of water and kept on increasing in moisture for very much longer periods of time. The

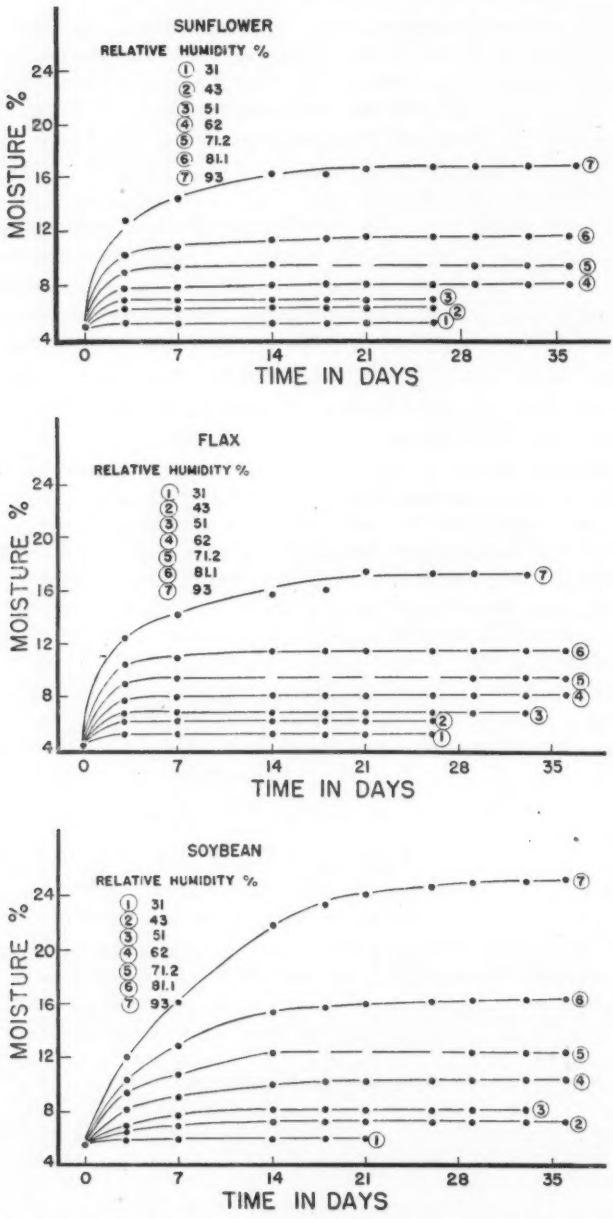

FIG. 1. *Changes in moisture content of sunflowerseed, flaxseed, and soybeans exposed to various relative humidities for a period of 36 days.*

time curve for soybeans is distinctly different from those of sunflowerseed and flaxseed. This seems somewhat surprising in view of the greater oil content of flaxseed. One might suppose that it would take longer to absorb water in a highly oleaginous seed than in one of lower oil content, but these data indicate the reverse conclusion.

The equilibrium moistures at various *R.H.*'s for the three grains, and for sunflower meats, are given in Table III, and are shown graphically in Fig. 2.

TABLE III

EQUILIBRIUM MOISTURE CONTENTS FOR SUNFLOWERSEED, FLAXSEED, SOYBEANS, AND SUNFLOWER MEATS AT VARIOUS RELATIVE HUMIDITIES

R.H.	Moisture content, %			
	Sunflowerseed	Flaxseed	Soybean	Sunflower meats
31.0	5.2	5.3	6.1	4.7
43.0	6.3	6.4	7.4	5.3
51.0	6.9	6.9	8.3	6.1
62.0	8.1	8.2	10.4	8.8
71.2	9.5	9.5	12.4	—
81.1	11.7	11.6	16.4	—
93.0	16.9	17.1	25.1	—

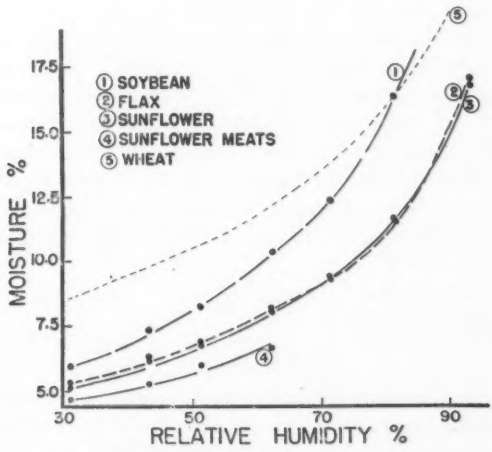

FIG. 2. *Equilibrium moistures on the per se basis.*

These moistures are expressed as moisture contents of the grain rather than on the dry-matter basis because this is the basis on which grains are handled commercially. Included in Fig. 2 is the curve for wheat, drawn from the data of Coleman and Fellows (1). The curve for flaxseed agrees very closely with the data of Coleman and Fellows, and the curve for soybeans practically coincides with that given by Ramstad and Geddes (2).

It should be noted that sunflowerseed gives a hygroscopicity curve almost identical with that of flaxseed although it is very much lower in oil content, the values being 28.3% for sunflower and 42% for flaxseed. Coleman and Fellows (1) sought to explain the lowering of the curve for flaxseed below the curves for the cereal grains, on the basis of the high oil content. Ramstad and Geddes (2) point out that at 70% *R.H.* the hygroscopicity curve for soybeans falls intermediate between cereals and flax, a result that might be predicted from the fact that the oil content is about 50% lower than flaxseed. It is obvious that this explanation cannot be applied to sunflowerseed. Whole sunflowerseed is very different in physical structure from the other grains because it has a heavy outer hull amounting to about 50% of the total weight of the seed. As this hull is relatively low in oil and high in cellulosic fibre, it may have some sort of counterbalancing effect on the water equilibrium in the whole seed. The dehulled seed, the "meat", should be more directly comparable to flax and soybeans. Unfortunately, the equilibrium moistures were obtained on the meats only up to *R.H.* of 62%.

Ramstad and Geddes (3) have commented on the fact that at lower *R.H.*'s soybeans approach flax in hygroscopicity, while at higher *R.H.*'s this grain exceeds the cereal grains in hygroscopicity. This is confirmed by our data. Our data do not, however, lend much support to their postulate that this change in relative hygroscopicity may be attributable to the differences in ash content.

If one wishes to compare such properties as ash, protein, or carbohydrate contents of these seeds in respect to probable effects on hygroscopicity, it is obviously necessary to examine the data on the oil-free basis, if it may be assumed that the oil itself plays no part in the absorption and retention of water. The oil content of these seeds varies over such a wide range that it is almost impossible to compare them per se, in respect to the effects of the non-oil components. By calculating the data to an oil-free basis, one has the moisture in relation to the components that may be regarded as responsible for the retention of it.

The data of Table III, recalculated to an oil-free basis, are given in Table IV and shown graphically in Fig. 3.

TABLE IV

DATA OF TABLE III CALCULATED TO AN OIL-FREE BASIS

Relative humidity, %	Moisture content			
	Sunflowerseed	Flaxseed	Soybeans	Sunflower meats
31	7.1	8.9	7.1	9.1
43	8.6	10.6	8.7	10.1
51	9.3	11.4	9.7	11.6
62	10.9	13.3	12.2	12.8
71.2	12.7	15.2	14.4	—
81.1	15.6	18.6	19.0	—
93	22.0	26.3	28.5	—

Referring to Fig. 3, it can be seen that the curves for flaxseed and whole sunflowerseed are practically parallel, up to *R.H.* of 70%, with the latter considerably below the flax. Above 70% *R.H.* the sunflowerseed curve rises

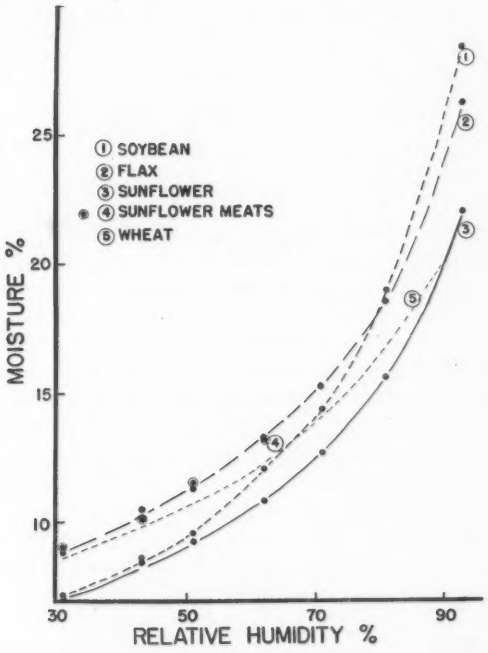

FIG. 3. *Equilibrium moistures calculated to the oil-free basis.*

more steeply than the flaxseed curve. Sunflower meats, up to and including *R.H.* of 62%, fall on the flaxseed curve. The curve for soybeans starts on the lower of the two curves and crosses the higher curve at *R.H.* of about 80%. Wheat behaves in quite the reverse fashion, starting out on the upper curve and apparently crossing the lower curve at *R.H.* of about 90%. The wheat and soybean curves cross at *R.H.* of about 66%.

While the ash explanation may be applicable to the differences between soybeans and wheat, it certainly fails with the other oil seeds. It can be seen in Table V that soybeans and flaxseed have practically the same ash content on an oil-free basis, and yet the hygroscopicity curves are very different. On the other hand, whole sunflowerseed, having a lower ash than flaxseed, tends to rise more steeply after 70% *R.H.* It is evident that neither oil content nor ash are sufficient to account for the differences in these curves.

Any adequate explanation of these differences will likely have to be found in the nature of the components of these seeds rather than in the actual amounts of the various components present. Although these conclusions

TABLE V

AVERAGE VALUES FOR ASH AND PROTEIN ON THE OIL-FREE DRY-MATTER BASIS (DATA FROM WINTON AND WINTON (4))

Grain	Ash, %	Protein, %
Sunflowerseed (whole)	4.74	22.7
Sunflower meats	8.47	52.4
Flaxseed	6.89	45.0
Soybean	6.77	45.1
Wheat	1.93	14.1

have been based on the oil-free compositions, it should not be overlooked that the manner in which the oil is distributed in the seeds may have an important influence on the rate of water uptake and the tenacity with which it is held in the structure of the seed.

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RESPIRATION OF WHOLE AND DEHULLED SUNFLOWERSEED AND OF FLAXSEED[1]

By R. K. Larmour[2], H. R. Sallans[3], and B. M. Craig[4]

Abstract

The effects of various moisture contents on carbon dioxide production of whole and dehulled sunflowerseed and of flaxseed were studied. The safe moisture limit for straight grading of whole, undamaged sunflowerseed intended for bulk storage was estimated to be 9.5%; for dehulled sunflowerseed it appears that 6% must be regarded as a maximum moisture for safe storage.

Introduction

The present shortage of vegetable oils in Canada has turned the attention of commercial and agricultural interests to the possibilities of producing a greater proportion of our total oil requirements within the country. At present three major crops, namely flax, sunflower, and soybeans are receiving attention. Flax is adapted to the climatic conditions of Western Canada and its production has been notably increased to meet an enhanced demand for drying oils. Sunflower is also well adapted to the Prairie Provinces and has been grown in small amounts for many years. The oil from sunflowerseed is semidrying, and since it can be readily refined and deodorized it is admirably suited for human consumption. The soybean is not so widely adapted to Canadian climatic conditions as flax or sunflower, but it can be grown satisfactorily in certain areas, such as the southern parts of Ontario, Manitoba, and Alberta, where the frost-free period is long enough to allow the crop to mature. Thus for the large-scale production of edible oil of high quality, sunflower appears to offer the greatest promise in Western Canada.

As flax has long been produced as a commercial grain crop, grading standards for it are well established. Soybeans has been a major commercial crop in certain areas in the United States and a great deal of information is available regarding the storage and handling of this crop. Sunflowerseed has not been produced in commercial quantities in either Canada or the United States and therefore it is necessary to obtain information regarding the limits of moisture for commercial storage of this grain. Although substantial quantities of this seed have been produced in Argentina and Russia for many years, definite information regarding its commercial handling is hard to obtain and there is some doubt that such information would be applicable to conditions in Western Canada. It was deemed necessary, therefore, to investigate a

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number of factors involved in the handling of the sunflowerseed crop coming to market this autumn.

The principal questions that demand answers are, (1) what is a safe moisture content for storage of these seeds in bulk, (2) what is likely to be the effect of threshing damage on the storage of this grain, and (3) can the seeds be safely dehulled prior to shipping and storage? In view of the urgency of these problems the authors present the following data and discussion as offering tentative answers that may be of use till more complete data are available.

It has been shown by Larmour, Sallans, and Craig (3) that the hygroscopic equilibrium curves for whole sunflowerseed and flaxseed are almost identical. One might conclude from this that the safe moisture content of sunflowerseed would be the same as for flaxseed, namely 10.5%. Sunflower seeds however are much different from flax seed in physical structure. The hull comprises 40 to 50% of the total weight of the seed. The meat, or kernel, is not closely attached to the hull and the amount of free space between the meat and the hull varies considerably with the degree of maturity, the conditions of growth, and the variety. The large seeded variety Mennonite has a heavier hull and greater free space than the smaller seeded variety Sunrise. The moisture of the whole seed is not uniformly distributed, the meats containing less than the hulls, which indicates that the hulls have the higher hygroscopicity. In a mixture of meats and whole seeds at equilibrium the meats contained 7.3% moisture and the whole seeds 9.1%. As the seed is virtually two separate structures of differing hygroscopicities it is difficult to predict how it may react at total moisture contents high enough to favour the growth of moulds.

There are two criteria of safe moisture limits for the storage of grain, namely, the rate of temperature change, and the rate of carbon dioxide production at various moisture levels. Laboratory-scale heating experiments can be done satisfactorily with the Working adiabatic respirometer described by Ramstad and Geddes (4), but this procedure is slow unless one has a number of these instruments available. Only one moisture content can be studied at a time, and the study must be continued until a moisture level is found at which the grain shows no rise in temperature over a long period of time.

A rough method was used with wheat by Larmour, Clayton, and Wrenshall (2). They used 15-lb. samples in earthenware jars insulated with planer shavings. This method is not very satisfactory because even with the best of insulation it is impossible to prevent heat loss if one maintains an adequate supply of air at the surface of the sample. Dewar flasks were not satisfactory because they did not hold enough material to heat fast enough to overcome radiation losses near the critical moisture level. Somewhat better results were obtained when the flasks were packed in shavings. However data obtained by this method could only be considered a very rough approximation of that which would be obtained from bulk storage of grain.

Measurements of the rate of carbon dioxide production at various moistures appeared to be a more promising method of attack on the problem. The

equipment required is relatively simple and a considerable number of determinations may be made simultaneously thus reducing the time required to obtain reasonably accurate data.

The rate of carbon dioxide production of grains is influenced by several factors, the principal being, (1) temperature, (2) moisture content of the grain, (3) the presence of growing fungi, (4) the frequency of aspiration, and probably the previous treatment of the grain. A discussion of these factors in relation to carbon dioxide production of wheat has been given by Larmour, Clayton, and Wrenshall (2) and need not be repeated here.

It is not possible to duplicate in the laboratory the conditions to be found in commercial bulk storage of grain. Grain in large bins may rise in temperature owing to the insulating capacity of large masses of grain. Then the carbon dioxide production of the embryo accelerates, and in addition, whatever mould spores are present may germinate, and the fungus commence to propagate actively on the grain. The metabolism of the growing fungi usually produces far more carbon dioxide than the embryo of the seed. Thus at a moisture content high enough to permit the germination and growth of fungus spores present in, or on the grain, the carbon dioxide produced comes from the respiration of both the grain and the fungi. Therefore the term "respiration of grain", unless conditions are known to be such that fungi cannot germinate and grow, refers to the sum of the respirations of the grain and whatever fungi may be growing on it. The beginning of active mould growth is usually marked by a sharp rise in carbon dioxide production which occurs even before the presence of the mould can be detected by the naked eye.

Of the many different methods that have been employed for the estimation of respiration rates of plant materials, the simplest and most practical for cereal grains appears to be that of Bailey and Gurjar (1), or simple modifications of it. This procedure involves the use of relatively large amounts of grain from which the carbon dioxide is aspirated into standard barium hydroxide solution at regular intervals. It is an isothermal reaction in which the samples are kept at a definite temperature by means of a thermostat of some sort.

Method and Material

The procedure adopted for this study was as follows: 180 gm. of the tempered grain was placed in drying towers of approximately 250 ml. capacity with top and bottom openings. These were kept in a constant temperature room at 25° $\pm$ 0.4° C. They were aspirated with carbon-dioxide–free air the last hour of each 24-hr. period, the carbon dioxide being collected in standard barium hydroxide solution in a 30-in. bead tower. The aspirating stream of air was washed by passing it through a bead tower of dilute sodium hydroxide solution and then brought back to the correct humidity by passing it through another tower containing a saturated salt solution having a vapour pressure equal to that of the particular grain sample (3).

The sunflowerseed used in this study consisted of a mixed lot of breeding stock obtained from the Dominion Forage Crops Branch at Saskatoon. It

consisted of strains of the large seeded type known as Mennonite. The flaxseed was Bison of No. 1 seed grade, grown at the University of Saskatchewan. These samples had been stored at room temperature for some time and were of rather low moisture content. They were tempered by adding the appropriate amount of water and shaking in air-tight containers.

As it was desirable to obtain information regarding the effect of damaged grains, especially in the case of sunflowerseed in which threshing damage may be expected to be somewhat higher than in smaller grains, determinations were also made with completely dehulled seeds, and with a mixture of whole, dehulled, and broken seeds. Information regarding the dehulled seeds is important in connection with the problem of transportation. As the hull comprises 40 to 50% of the total weight of the seed, and as the whole seed is very bulky compared to the kernel, it may be anticipated that the question of hulling the seeds before shipment to the processing plants inevitably will be raised.

Discussion of the Data

The results obtained are all shown in the form of graphs in the interest of clarity. Individual points for the graphs have been included for greater ease of ascertaining the original data if these are desired.

Flaxseed

The carbon dioxide production rates for flaxseed at moistures of approximately 12, 13, 14, and 16.5% are shown in Fig. 1. At the 14% moisture level the carbon dioxide production rate rose markedly after the eighth day and mould growth was visible to the naked eye on the 10th day after tempering. This moisture level is therefore decidedly unsafe. At the 12% level, the rate of carbon dioxide production was less than 1 mg. per 24 hr. and it showed no indication of acceleration during the course of the experiment. This does not necessarily mean that flax at 12% moisture will not heat in bulk storage. It was found by Larmour, Clayton, and Wrenshall (2) that wheat at 16% moisture showed no acceleration of carbon dioxide production under similar laboratory conditions. Nor did they find any evidence of a tendency to heat in 15-lb. lots at this moisture. However, it has to be admitted that in both these experiments there was much greater chance for heat loss than in a commercial grain bin filled with grain. As a result of those experiments they concluded that as the commercial limit for sound wheat is 14.5% moisture, a reasonably safe correction for laboratory results would be 1.5%. In other words, if the safe moisture limit ascertained by laboratory study were reduced by 1.5% actual, the corrected value might be regarded as a conservatively safe commercial moisture limit.

Until more extensive data are obtained on this question this correction is the best figure available. In the instance of flaxseed it appears as though this correction is applicable also, because there is no indication of increase in carbon dioxide production at 12% moisture, while the commercial limit, determined from commercial experience over a long period of time, is 10.5%.

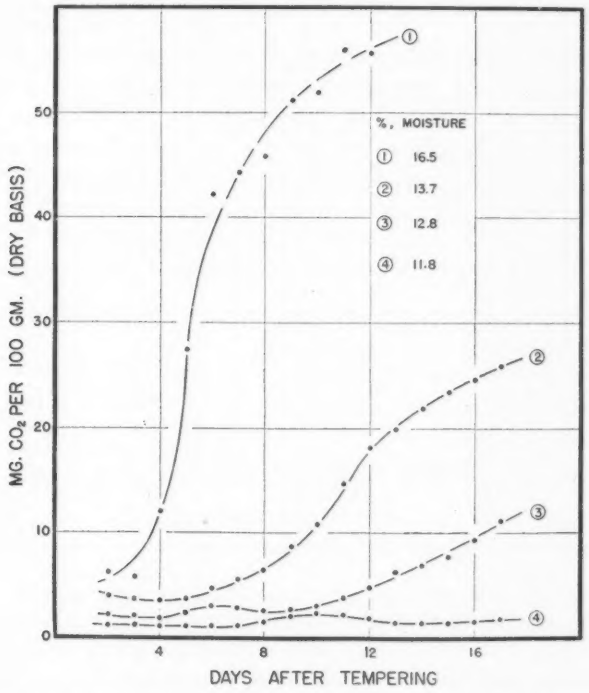

FIG. 1. *Carbon dioxide production of flaxseed at various moisture contents.*

It is fully realized that this conclusion is purely empirical. However while a discrepancy of 1.5% between laboratory and commercial findings seems excessive, it should be borne in mind that the laboratory data were obtained on sound seed of No. 1 grade while commercial limits must apply to all grades of the grain. The precise evaluation of the moisture limit for heating grains must await the data obtainable with the adiabatic respirometer or from bulk storage under standardized conditions.

Whole Sunflowerseed

The data obtained with whole sunflowerseed are given graphically in Fig. 2, where are shown graphs for seed at approximately 10, 11, 12, 13, and 14% moisture contents. In addition to these, determinations were made at 9 and 17.6% but these data have not been included as they contribute nothing to the conclusions. At 9% moisture the curve is a straight line practically coincidental with that at 10%, while at 17.6% moisture the curve merely rose earlier and much more sharply than the curve for 14% moisture.

At 10% moisture there was no significant change in the rate of carbon dioxide production of the whole sunflowerseed but at 10.8% there was a distinct and sustained increase in rate after the 15th day. It must therefore

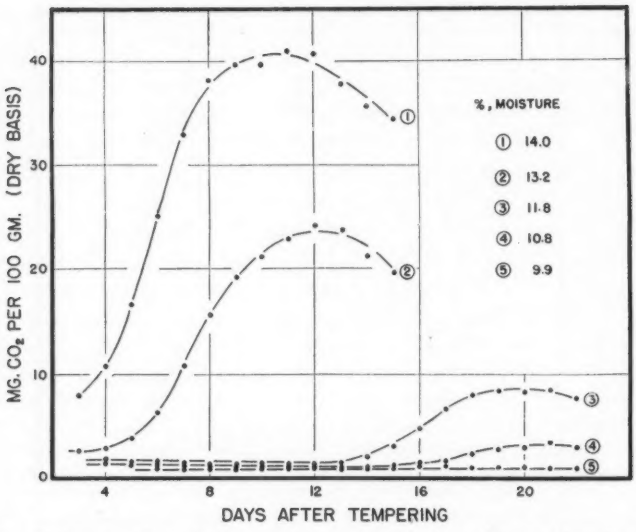

FIG. 2. *Carbon dioxide production of whole sunflowerseeds at various moisture contents.*

be concluded that this moisture content is unsafe for bulk storage. The rate of carbon dioxide production, after remaining almost constant at about 0.9 mg. for 15 days after tempering, suddenly accelerated to about thrice this value, indicating that mould had begun to grow on the grain. No condition that permits even a very small growth of fungi ought to be considered safe for long-time bulk storage. If fungi can germinate under laboratory conditions such as we have described, where any surplus heat is rapidly dissipated, it is reasonable to assume that in large elevator bins or cars, the growth of fungi would continue and accelerate with rise in temperature.

We must admit the possibility that the increase in rate discussed above may not be a result of fungus germination and growth; it might result from changes in the embryo that cause it to respire at a greater rate. The actual rate recorded in Fig. 2 for the 10.8% moisture level is in itself probably no cause for great concern if one could be certain that it is the result of embryonic activity only, because it appears doubtful that such a low rate of activity could cause a serious accumulation of heat in a loose bulky grain such as sunflowerseed in which the ratio of voids to solids is so much greater than in the common cereal grains. But until this question is given more detailed study it should be assumed that 11% moisture is on the borderline of danger for the storage of sunflowerseed under laboratory conditions.

If we were to deduct the correction noted for wheat and for flaxseed, namely 1.5%, it would mean that the safe moisture limit for commercial bulk storage of whole sunflowerseed would be placed at 9.5%. In view of the bulkiness of this grain, 9.5% may be too low, but on the basis of presently available data it is the highest value acceptable for whole seeds.

Dehulled Sunflower Seeds

Dehulled sunflower seeds, "meats", were prepared from fairly uniform grain of the Mennonite type, by use of a laboratory hulling machine. The meats were screened and separated into whole and broken meats. These were tempered to 6, 7, 8.5, 10, 11, and 12% moisture levels and studied similarly to the whole seeds. In Fig. 3 are shown graphically the results with the 7, 8.5, and 10% levels, for both the whole and the cracked meats. The data for 6, 11, and 12% moisture levels were omitted from Fig. 3 because they add nothing to the conclusions.

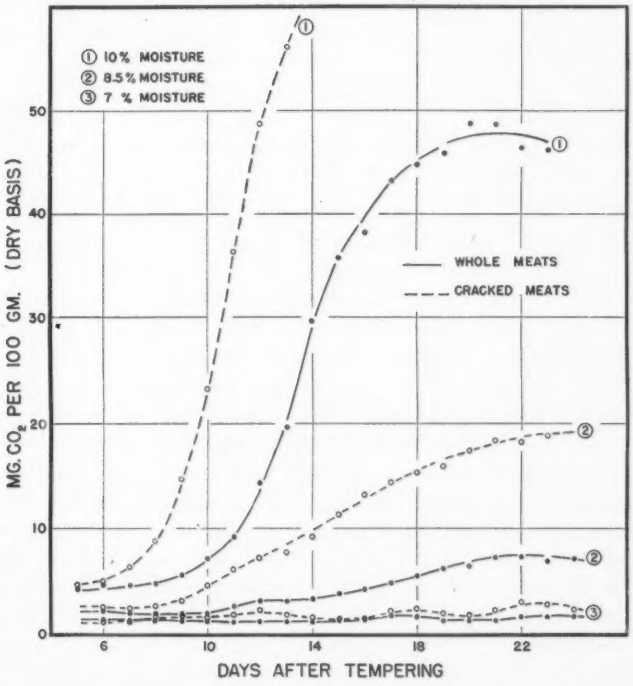

FIG. 3. *Carbon dioxide production of sunflower meats at various moisture contents.*

Considering first the whole meats, it can be seen that at 7% moisture the rate of carbon dioxide production was practically constant for 24 days at a value of approximately 1.5 mg. per 100 gm. per 24 hr. Slight variations in the daily values may be attributable to experimental error. But at 8.5% moisture, the rate commenced to rise after 10 days and by the 21st day had reached a value of 7.25 mg. carbon dioxide per 100 gm. per 24 hr., a rate slightly more than four times the initial rate. At 10% moisture the rate increased rapidly to over 40 mg. by the 17th day.

It must be concluded from these data that 8.5% moisture content is too high for whole meats even under laboratory conditions. It seems probable that the highest admissible moisture content for safe bulk storage would be 7%. A safer value to accept would be about 6%.

The broken meats showed higher rates of carbon dioxide production at the same moisture contents. Unquestionably, at 8.5% the increase in rate was more rapid and the final rates were about two and one-half times higher than for the undamaged meats, 18 mg. as compared to 7.25 mg. At 7% moisture, the broken meats started off at about the same rate as the whole meats but by the 17th day they showed signs of greater activity, although the experiment was not continued long enough to prove definitely that this is true. However, judging by the values at 8.5% moisture, it seems safe to conclude that if the safe moisture limit for whole meats were to be taken as 7%, that for damaged meats would have to be at most 6%. This means, of course, that the limit for meats in general would have to be under 6% because it seems unlikely that commercial samples free from broken meats could be obtained with the machinery available at the present time.

General Discussion

The difference in behaviour between whole and broken kernels is not surprising, but on the contrary is just what one would expect where moulds are involved. Wheat in which the viability has been destroyed or markedly lowered, is more susceptible to mould growth than viable grain; and the seeming preference of moulds for damaged parts of larger organisms is too well known to need discussion. This becomes a serious deterrent to dehulling sunflowerseed prior to shipping, especially in view of the relative fragility of the kernel as compared to other grains of comparable size and shape.

This great difference in safe moisture limits for whole seed and meats introduces the question of whether it will be possible to fix "straight grade" moisture limits for all the grades of sunflowerseed that may be set up. Presumably one of the grading factors to be taken into account in fixing grades will have to be the amount of damaged and broken grains. But it is apparent that damaged seeds not only affect the sales value of the grain but also the capacity for storage at certain moistures. With 20% hulled seeds the limiting moisture content would have to be reduced considerably as indicated in Fig. 4. Mixtures containing 80 gm. of whole seeds and 10 gm. of whole kernels were studied at 11 and 12% moistures. Rate curves for the whole seeds and the whole meats are given in this figure for comparison. It can be seen that with only 11.1% of dehulled seeds there was a pronounced acceleration in carbon dioxide production at 11% moisture content. This would indicate that the safe moisture limit for such a mixture would be somewhat below 9.5%, if we applied the correction for laboratory results previously discussed.

There is here a difficulty not ordinarily encountered in the grading of grains, inasmuch as the presence of dehulled seeds in a sample of sunflowerseed is actually an advantage to the buyer because the more dehulled seeds there

are present, the higher will be the oil yield of the sample. There may therefore be a tendency to overlook the presence of dehulled seeds, or at least to consider it a not too serious degrading factor. In the light of the foregoing discussion this might cause loss by heating if the sample were at the upper moisture limit for "straight grade".

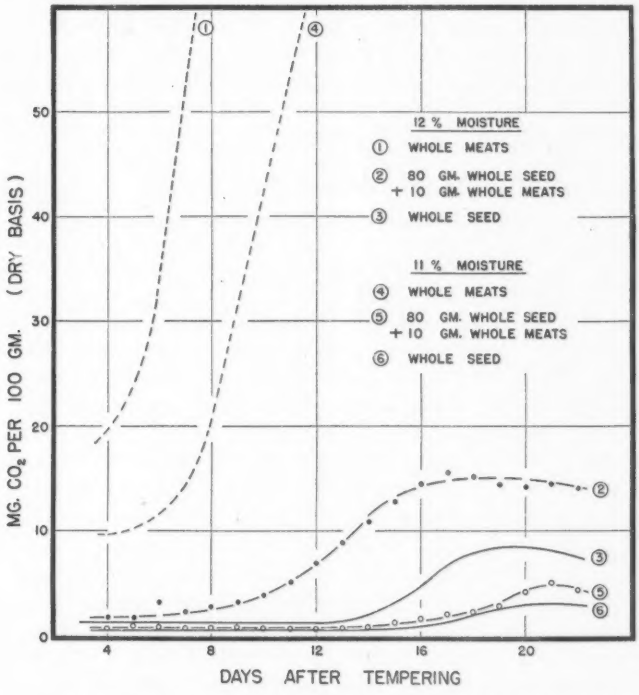
MG. CO_2 PER 100 GM. (DRY BASIS)
DAYS AFTER TEMPERING
12 % MOISTURE
① WHOLE MEATS
② 80 GM. WHOLE SEED + 10 GM. WHOLE MEATS
③ WHOLE SEED
11 % MOISTURE
④ WHOLE MEATS
⑤ 80 GM. WHOLE SEED + 10 GM. WHOLE MEATS
⑥ WHOLE SEED

FIG. 4. *Carbon dioxide production of sunflower whole meats, whole seeds, and a mixture of the two, at various moisture contents.*

In conclusion it should be emphasized that the moisture limits for safe bulk storage of any grain must be applicable to all the conditions under which the grain may be stored from the time it is threshed until it reaches the final user. It must be suitable for the large bins of terminal elevators as well as for the farmers' small bins. It must be suitable for high summer temperatures because there can be no assurance that the grain will be in storage only during the cool weather of Canadian late autumn and winter. In short, a moisture limit, to be useful in commercial grading, must be low enough to ensure that the grain admitted to "straight grades" can be stored and shipped under all temperature conditions that might be encountered in any season of the year within the country, or en route to the eventual market. It has been reported by several growers of sunflowerseed that they have stored seed over the

winter at moistures said to be as high as 16 to 17%, without damage. It should be pointed out that at threshing time, about the third week of September, the temperatures are low and there is little likelihood of the grain getting above 50° F. from time of threshing until seeding time the following spring. Such observations, however, have little direct bearing on the problem of commercial grades, because they do not take into account the dangerous period for storage, namely, the summer months when temperatures in the tops of grain storage bins may easily go above 100° F. Consequently, although the moisture limit of 9.5% for "straight grade" sunflowerseed may seem extraordinarily low, we must still insist that for grading use it is as high as is justified by the data available at the present time.

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OIL SEEDS IN WESTERN CANADIAN GRAIN SCREENINGS[1]

By J. A. Anderson[2], W. O. S. Meredith[3], W. J. Eva[3], and A. C. Heise[4]

Abstract

An examination of the refuse screenings from cereal grains, shipped from the Lakehead in the second quarter of the 1942–43 crop year, shows that it contained an average of 49% of weed seeds, having an oil content of 14.6%. The principal oil-bearing seeds in these screenings were: wild mustard, 8.8%; stinkweed, 2.9%; broken flax, 2.4%; hare's ear mustard, 1.6%; and tumbling mustard, 0.9%. The amounts of total seeds and of individual species varied widely in different shipments.

During the same period, refuse screenings from flax contained an average of 75% of weed seeds, and other small heavy material, having an oil content of 21.4%. The principal oil-bearing materials were: broken flax, 13.8%; wild mustard, 11.7%; stinkweed, 9.4%; hare's ear mustard, 5.0%; and tumbling mustard, 2.8%.

While limited crushing capacity and the man-power shortage make it unfeasible to produce oil from screenings at present, the future possibilities merit consideration.

The shortage of vegetable oils on the North American continent, and particularly in Canada, makes it necessary to examine all sources of supply. Among these, the oil seeds in the refuse screenings collected in terminal elevators at Fort William and Port Arthur present certain possibilities. A careful survey was made in 1933 by Hopkins (2). He separated the various oil seeds, examined their oil content and the characteristics of the oils, and suggested methods for obtaining and utilizing the oils and the other principal components of refuse screenings. He also estimated the amounts of oil, etc., available in screenings, but his figures are based on the study of a single sample, representing one 3000 ton cargo drawn from eight elevators at the Lakehead. The bushel weights of shipments of screenings vary widely, and it seemed certain that corresponding variations would occur in the oil content of the screenings. This matter has been examined in order to obtain an additional estimate of the average amounts of oil seeds and oil in screenings.

Materials and Methods

Regulation No. 50 of the Board of Grain Commissioners specifies only one grade of refuse screenings, but permits the grain inspector to "make notations as to the kind and condition". It is the general practice in the terminals at the Lakehead that handle large quantities of flax to segregate the refuse screenings from it, and these are classified by the grain inspector as "Refuse

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Screenings (Flax)". The name "Refuse Screenings" is thus restricted to screenings obtained mainly from all grains and seeds other than flax.

Representative samples of all shipments of refuse screenings leaving Fort William and Port Arthur are taken by the Inspection Branch of the Board of Grain Commissioners. All those taken during the second quarter of the 1942–43 crop year, November 1, 1942, to January 31, 1943, were made available for this study. They represented 190 carlots (approximately 4800 tons) of refuse screenings and 56 carlots (approximately 1400 tons) of refuse screenings (flax). Seventeen samples of wild mustard, obtained principally from carlot shipments of "black seeds", were also available for study.

A preliminary separation of the weed seeds and other small heavy materials from the straw, chaff, dust, and any large portions of wild oats or other grains that remained in the screenings, was made by passing them first through an Emerson Kicker and then through a Clipper Cleaner operated with full air blast and a No. 12 sieve. The material that remained was weighed and reported as percentage "total seeds, etc." in the original sample. The seeds were then composited in accordance with the bushel weights of the original sample. There were thus obtained 25 composite samples representing refuse screenings covering a range in bushel weight of 14 to 42 lb., and 19 composite samples representing refuse screenings (flax) covering a range in bushel weight of 25 to 46 lb.

The 17 samples of black seed were treated by sifting out the small seeds and chaff and then rolling out the wild mustard seed by gentle shaking on an inclined board.

Determinations of the amounts of the different species of seeds in the samples were made by hand picking a 1 gm. sample. Oil content, iodine value (Wijs'

TABLE I

AVERAGE PERCENTAGES OF PRINCIPAL WEED SEEDS IN REFUSE SCREENINGS AND REFUSE SCREENINGS (FLAX) SHIPPED FROM THE LAKEHEAD BETWEEN NOVEMBER 1, 1942, AND JANUARY 31, 1943

Name	Refuse screenings		Refuse screenings (flax)	
	Mean	Range	Mean	Range
Wild mustard	8.8	3.9 – 27.7	11.7	4.5 – 31.0
Stinkweed	2.9	1.3 – 14.6	9.4	6.3 – 12.4
Hare's ear mustard	1.6	0.3 – 18.8	5.0	1.7 – 18.0
Tumbling mustard	0.9	0.2 – 5.6	2.8	1.0 – 4.6
Dog mustard	0.12	0 – 9.3	0.10	0 – 0.4
Ball mustard	0.20	0 – 1.1	0	—
Wormseed mustard	0.03	0 – 0.2	0.02	0 – 0.2
Broken flax	2.4	—	13.8	9.0 – 17.0
Lambsquarters	15.2	8.8 – 27.0	13.7	5.6 – 21.8
Russian pigweed	0.7	0.2 – 1.4	0.7	0 – 2.0
Pigweed	0.6	0 – 8.5	5.5	1.7 – 11.5
Peppergrass	0.01	0 – 0.2	0	—
Western false flax	0.01	0 – 0.1	0.04	0 – 0.3
Flixweed	0.01	0 – 0.1	—	—

units), and acid number of the oil were determined by the official methods of the *A.O.A.C.* (1).

Results

The data on the composition of the samples of refuse screenings and refuse screenings (flax) are summarized in Table I. Hopkins found that the principal oil seeds in the 3000 ton cargo of refuse screenings that he examined were wild mustard, stinkweed, and hare's ear mustard, and this conclusion is substantiated by the present study. However, whereas Hopkins reported the percentages for these three weeds as 13.3, 8.3, and 4.7%, a total of 26.3%, our samples of refuse screenings show an average of 8.8, 2.9, and 1.6%, which with 2.4% of broken flax and 0.9% of tumbling mustard gives a total of 16.6%. On the other hand, the amounts of these seeds in our samples of flax screenings were 11.7, 9.4, 5.0, and 2.8%, and to this must be added 13.8% of broken flax, so that the total amount of these seeds in flax screenings is about 42.7%.

Dog mustard, ball mustard, and wormseed mustard, occur in only small percentages. The remaining weed seeds listed in Table I are not classed as oil seeds though all of them contain some oil.

Data for each of the composite samples of refuse screenings are given in Table II. The average bushel weight was 23 lb. and the majority of the

TABLE II

PERCENTAGES OF PRINCIPAL OIL SEEDS IN COMPOSITE SAMPLES OF REFUSE SCREENINGS OF DIFFERENT BUSHEL WEIGHTS

Bushel weight, lb.	No. of carlots represented	Total seeds, etc., %	Oil-bearing seeds					
			Wild mustard, %	Stinkweed, %	Hare's ear mustard, %	Tumbling mustard, %	Other mustards, %	Total %
14	3	21	3.9	1.3	0.6	0.2	0.1	6.1
15	4	26	4.9	2.4	1.8	0.3	0.2	9.6
16	4	29	4.6	2.0	1.8	0.8	0.1	9.3
17	9	36	6.6	1.4	1.0	0.7	0.1	9.8
18	7	35	5.5	1.8	0.9	0.9	0.2	9.3
19	16	42	8.0	1.9	0.3	0.8	0.5	11.5
20	9	43	7.2	3.1	1.7	0.6	—	12.6
21	18	44	7.2	3.2	1.1	0.8	0.3	12.6
22	22	46	9.1	2.8	1.4	0.6	0.2	14.1
23	18	49	9.6	2.9	1.6	0.9	0.2	15.2
24	19	51	8.3	1.4	1.5	0.9	0.5	12.6
25	15	57	11.6	4.2	1.5	0.7	0.6	18.6
26	6	54	9.7	2.8	2.5	0.9	0.3	16.2
27	11	57	9.2	2.3	1.6	0.8	0.2	14.1
28	6	57	11.0	2.8	2.2	1.9	—	17.9
29	4	63	6.2	3.3	2.5	1.1	0.1	13.2
30	4	57	7.3	2.8	1.2	1.1	0.8	13.2
31	4	71	8.9	6.5	2.0	2.3	1.2	20.9
32	1	74	20.7	5.4	0.9	0.9	0.3	28.2
33	1	74	5.3	4.2	15.2	2.1	—	26.8
34	1	74	27.7	5.0	5.3	1.9	0.2	40.1
35	5	69	13.0	5.7	1.6	2.6	1.1	24.0
38	1	87	18.0	14.6	18.8	4.3	—	55.7
40	1	86	26.5	13.2	6.7	1.4	—	47.8
42	1	87	10.4	4.6	4.4	5.6	0.3	25.3

samples (77%) fall within ±5 lb. of this value. There is a close relation between bushel weight and the total amount of seeds and other small heavy material remaining after the initial cleaning process; the coefficients of correlation were .98 for the 25 composite samples, and .87 for the 190 individual samples from which the composites were prepared.

There is considerable variation in the percentages of total oil seeds and in the amounts of the individual species. The sample having a bushel weight of 38 lb. is particularly interesting; it had the highest percentage of total oil seeds, principally because it contained such large amounts of hare's ear mustard (18.8%) and stinkweed (14.6%). This sample and the sample weighing 33 lb. per bushel contained more hare's ear mustard than wild mustard. The sample weighing 40 lb. is also noteworthy because of the large percentage (13.2%) of stinkweed it contains. As would be expected, the correlation between oil seeds and bushel weight, namely, .80, is not as high as that between total seeds and bushel weight. It is clear, however, that if shipments of refuse screenings were being selected for oil extraction it would be advisable to segregate those having higher bushel weights.

Data for refuse screenings (flax) are given in Table III. The average bushel weight is 35 lb. which is approximately 50% higher than the figure for refuse screenings. Corresponding differences exist with respect to percentage of total seeds, etc., and total oil seeds, which are also very much higher for

TABLE III

PERCENTAGES OF PRINCIPAL OIL SEEDS IN COMPOSITE SAMPLES OF REFUSE SCREENINGS (FLAX) OF DIFFERENT BUSHEL WEIGHTS

Bu. wt., lb.	No. of carlots rep.	Total seeds, etc., %	Oil-bearing seeds						
			Wild mustard, %	Stink-weed, %	Hare's ear mustard, %	Tumbling mustard, %	Other mus-tards, %	Broken flax, %	Total, %
25	1	55	6.9	8.0	2.9	3.0	—	9.6	30.4
26	1	50	5.1	7.4	6.2	1.4	—	11.5	31.6
27	1	60	6.1	6.3	3.1	3.0	—	13.3	31.8
28	3	66	4.5	7.8	3.4	2.6	—	14.6	32.9
29	2	67	6.2	9.7	5.4	1.8	—	16.7	39.8
30	4	72	10.4	11.1	4.5	1.7	—	17.0	44.7
31	2	75	8.6	11.1	7.4	3.0	—	16.4	46.5
32	2	75	10.9	8.0	7.4	1.7	—	16.1	44.1
33	2	76	13.0	10.5	7.8	2.7	—	16.5	50.5
34	3	78	21.0	12.4	6.1	2.2	—	12.4	54.1
35	6	76	7.2	6.6	4.0	3.6	0.3	12.6	34.3
36	5	77	7.2	7.2	7.5	4.6	0.4	11.5	38.4
37	7	78	10.4	9.2	1.9	2.5	0.2	14.1	38.3
38	7	76	15.9	11.9	6.1	3.3	0.2	14.1	51.5
39	2	78	12.8	9.6	2.9	2.2	0.2	14.4	42.1
40	3	81	7.8	9.2	2.4	3.9	0.2	12.0	35.5
41	3	82	28.4	10.4	4.4	2.9	—	13.1	59.2
43	1	82	31.0	7.8	1.7	1.6	—	9.0	51.1
46	1	85	27.7	8.7	18.0	1.0	0.1	12.7	68.2

flax screenings. On the other hand, the correlation coefficients between bushel weight and total seeds (.88) and between bushel weight and total oil seeds (.69) are not as high as the corresponding coefficients for refuse screenings. This doubtless results mainly because the number of carlots per composite sample is lower for flax screenings.

On the whole, the variations in the amounts of the individual weed seeds in flax screenings are much the same as the corresponding variations in refuse screenings. It will be noted that in both refuse screenings and flax screenings there is on the average about twice as much stinkweed as hare's ear mustard. On the other hand, the ratio of wild mustard to stinkweed is much lower in the flax screenings than in the refuse screenings. It is possible that these ratios may reflect differences in the percentages of the various weeds growing in flax and other grain fields, but it is also possible that the data indicate only that some of the flax screenings had previously been processed for the recovery of wild mustard. The processing of screenings from cereal grains for the recovery of wild mustard is extremely rare, whereas flax screenings are occasionally treated for this purpose.

Table IV contains data on oil content and on the quality of the extracted oil. When the oil content is calculated as a percentage of the original screenings it is found that refuse screenings contain an average of 7.3% of oil, and that flax screenings contain 16.1%. However, if screenings are to be processed for the recovery of oil, it is certain that the straw, chaff, and other large material would be removed, and it is therefore of interest to consider the oil content of the remaining weed seeds. The figures are 14.6% for total seeds in refuse screenings and 21.4% for flax screenings. The amounts of oil in the original screenings vary considerably from sample to sample and tend to increase with increasing bushel weight; the correlation coefficients are .85 for refuse screenings, and .67 for flax screenings.

The average iodine value for the oil from refuse screenings is 131, whereas that for oil from flax screenings is 143. The latter figure is obviously higher because of the inclusion of appreciable amounts of linseed oil extracted from broken flaxseed. Average acid numbers for both oils are quite high, 4.4 for refuse screenings, and 5.7 for flax screenings. Here again, it may be assumed that the higher figure for oil from flax screenings results from the instability of the oil in the small pieces of broken flax.

Table V contains the data for the 16 samples of black seeds from which wild mustard was obtained. The oil contents of the wild mustard seed varied between 24.3 and 34.0%, the iodine values between 121 and 129 Wijs' units, and the acid values between 0.7 and 1.4 mg. of potassium hydroxide per gram. It appears that the variations in both oil content and iodine value are largely the result of differences in the ratios of *Brassica juncea* and *Brassica arvensis* in the samples. An estimate of the amounts of the two species in each sample was made and the data are shown in the table. It is surprising that out of 16 samples two should be pure *Brassica juncea* and two should be pure *Brassica arvensis*. This clearly suggests that there are con-

TABLE IV

DATA ON OIL OBTAINED FROM COMPOSITE SAMPLES OF REFUSE SCREENINGS AND REFUSE SCREENINGS (FLAX) OF DIFFERENT BUSHEL WEIGHTS

Class of screenings	Bushel weight, lb.	Total seeds, etc., %	Oil content of seeds, %	Iodine value of oil, Wijs' units	Acid number of oil, Mg. KOH/gm.
Refuse screenings	14	21	14.3	128	4.1
	15	26	16.0	130	3.3
	16	29	14.8	130	4.3
	17	36	13.3	131	4.6
	18	35	13.1	130	5.3
	19	42	15.5	128	5.2
	20	43	13.5	129	5.8
	21	44	14.1	131	3.8
	22	46	13.9	135	3.7
	23	49	14.0	128	5.4
	24	51	13.3	132	2.5
	25	57	16.6	130	4.5
	26	54	17.2	130	2.9
	27	57	12.7	133	4.2
	28	57	14.0	131	4.8
	29	63	12.2	131	4.8
	30	57	13.4	130	3.7
	31	71	16.2	136	6.0
	32	74	20.5	134	3.4
	33	74	14.6	125	3.9
	34	74	19.4	129	2.2
	35	69	18.4	136	6.4
	38	87	28.4	130	2.8
	40	86	26.2	136	5.8
	42	87	14.9	132	5.4
	Weighted mean	49	14.6	131	4.3
Refuse screenings (flax)	25	55	20.6	144	13.6
	26	50	20.8	143	5.5
	27	60	20.0	146	18.7
	28	66	21.0	145	14.8
	29	67	20.5	144	5.1
	30	72	21.2	144	4.6
	31	75	21.5	139	6.8
	32	75	20.2	142	4.2
	33	76	24.8	141	5.9
	34	78	22.5	137	3.1
	35	76	18.8	148	4.8
	36	77	21.8	141	4.1
	37	78	21.5	147	5.1
	38	76	22.4	139	4.9
	39	78	22.0	143	4.9
	40	81	17.8	147	4.1
	41	82	22.7	139	5.8
	43	82	26.0	136	2.9
	46	85	26.8	130	2.5
	Weighted mean	75	21.4	143	5.7

TABLE V

PERCENTAGES OF WILD MUSTARD, AND OIL THEREFROM, IN CARLOTS OF BLACK SEEDS

Wild mustard, %	Brassica juncea, %	Brassica arvensis, %	Oil content, %	Iodine value, Wijs' units	Acid number, Mg. KOH/gm.
91	100	0	34.0	121	0.8
89	100	0	31.8	121	0.7
92	60	40	30.0	124	0.7
74	40	60	25.8	123	1.3
77	40	60	28.7	127	0.8
48	40	60	25.2	121	1.1
79	40	60	29.7	125	0.8
70	40	60	32.7	123	0.9
78	40	60	30.3	124	0.8
70	40	60	29.2	123	0.8
91	40	60	32.8	123	0.7
56	15	85	25.4	126	1.4
48	10	90	24.3	128	1.1
43	10	90	24.9	129	1.2
99	0	100	25.6	128	1.1
87	0	100	25.0	129	1.2

siderable areas in Western Canada where only one of these two species occurs. The samples provided opportunity for examining the differences between these two species; the two samples of *Brassica juncea* had an average oil content of 32.9% and an average iodine value of 121 units, whereas the two samples of *Brassica arvensis* had an average oil content of 25.3% and an average iodine value of 129 units. Hopkins' figures for wild mustard are: oil content, 24.0%; and iodine value, 121 units. It seems probable that the somewhat higher oil contents and iodine values obtained in the present study were caused by the wet season of 1942.

One sample of ball mustard was also obtained; it contained 20.3% of oil, having an iodine value of 141 units. Hopkins gives 16% of oil and an iodine value of 140 units.

Discussion

In our opinion it is still impossible to state the average percentage of oil seeds in refuse screenings. The mean data given in this paper are fully representative of all screenings shipped from the Lakehead from November 1, 1942, to January 31, 1943; but the amount shipped during this period is only a small proportion of average annual shipments since the bulk of these are made by boat when the Lakes are open. Nevertheless, the distribution of the carlots with respect to bushel weight, with the bulk of the samples falling close to the mean, is normal, and presents strong presumptive evidence that the shipments were fully representative of screenings at the Lakehead, which should themselves be representative of the 1942 receipts from country elevators.

It has been mentioned previously that Hopkins' figures, which are considerably higher than those obtained in this investigation, were based on the

study of a single sample representing a 3000 ton cargo shipped from Fort William about 10 years ago. It may be that it was fully representative of the refuse screenings of the year in question; or it may be that it represented a particularly "rich" cargo purchased under an agreement with respect to minimum weight per bushel.

In this connection it should be pointed out that a private communication from one of the larger milling companies gives a figure of 3.8% for the wild mustard in refuse screenings examined in 1940. Hopkins' figure for wild mustard is 13.2%, and ours is 8.8%.

It is well known that there are wide variations in the prevalence of mustard in different parts of Western Canada, and that the ratio of weeds to grain is affected by the weather during the growing season. Corresponding fluctuations in the composition of screenings originating in different areas and different years must therefore be expected; and these are also affected by the practice of the farmers and country elevators in cleaning grain prior to shipment. The bulking that takes place at the Lakehead, and the extent to which manpower and price make it profitable to remove broken grains, buckwheat, wild oats, etc., from screenings, also affect composition. The differences among the carlots examined in the present study probably present a fair indication of the range in composition that may be expected. It may thus be that each of the three figures cited in the previous paragraph is fairly representative of the mustard content of the refuse screenings shipped in the years in question. Investigations extending over a period of years are required to settle this matter. In the interim it would appear that the amount of oil seeds or oil available in refuse screenings cannot be estimated with certainty.

Hopkins, basing his figures on screenings containing 60% of seeds having an oil content of 16%, and estimating a 90% recovery, arrives at a yield of 172 lb. of oil per ton of screenings. Our average figures indicate 49% of seeds having an oil content of 14.6%, or a yield of 129 lb. per ton. If an average of 50,000 tons of screenings were processed each year, the total yield of oil would be 6,450,000 lb. From the point of view of oil yield, refuse screenings (flax) are far more promising. The average figure shows 75% of seeds, broken flax, etc., having an oil content of 21.4%. A 90% recovery would therefore yield 289 lb. of oil per ton of screenings. During the five years 1935–36 to 1939–40, the average amount of refuse screenings (flax) shipped from the Lakehead annually was 890 tons; but the flax shipped to the elevators in these years averaged only 1,424,000 bu. In 1942 a crop of almost 15,000,000 bushels was harvested and an equally large crop is in prospect this year. Accordingly, it seems reasonable to assume that refuse screenings (flax) will amount to about 9400 tons, yielding about 2,700,000 lb. of oil.

Both refuse screenings and refuse screenings (flax) yield crude oils that may well be difficult to refine without excessive losses. It is probable that they would have to be used in the crude condition, presumably as core oil.

Oils of superior and more constant quality can undoubtedly be obtained by segregating the seeds of various types. With existing machinery, it seems

probable that only the wild mustard can be obtained in bulk in relatively pure condition. The seed is almost spherical and can be separated by rolling it out of the remaining seeds with spiral chutes, which have been in use for this purpose for many years. These spirals operate by gravity and require no power other than that required to feed in the screenings and dispose of the separations. But their capacity is small and they require vertical space for their installation, whereas other cleaning machinery can be placed on one floor. The setting up of enough spirals to handle any considerable amount of screenings, together with the rearrangement of cleaning machines and rerouting of flow sheets that would be required, would hardly be practicable unless there were expectations of a steady demand for mustard seed at a price considerably above that of refuse screenings. Although the prospects are not promising, it is interesting to estimate the amount of wild mustard that might be made available. On the basis of the figures obtained in this report, 50,000 tons of refuse screenings, and 9400 tons of refuse screenings (flax), contain about 5500 tons of wild mustard. If it is assumed that 60% of this can be recovered in a pure condition, that it contains 28.5% of oil, and that 90% can be extracted, the total yield of mustard seed oil will be about 1,400,000 lb.

As the crushing equipment available in Canada is not adequate to handle much more than one-third of the oil crops now being grown, and as there appears to be little prospect of a large increase in crushing or extraction equipment, it is difficult to believe that use can be made, at present, in Canada, of the oil available in screenings. However, the data recorded in this paper may serve for the re-examination of the possibilities at some future date. A time may well come when there will be idle crushing equipment in Canada, and improvements in the machines and methods available for separating seed and extracting oil can confidently be expected.

References

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